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Implementation of E-Worksheet Based on Problem-Based Learning Containing Education for Sustainable Development Use of Waste-Cooked Oil as a Washing Soap Ingredient to Improve Students' Critical Thinking Abilities

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Abstract

Improving the quality of education is necessary to face global challenges and avoid national backwardness through critical thinking skills. This study aims to implement and evaluate E-Worksheet based on problem-based learning (PBL) with education for sustainable development (ESD) content by raising the issue of managing used cooking oil waste as a material for making environmentally friendly laundry soap. This research is an impure experimental research (quasi-experimental) which is a follow-up to development research. The research subjects were 30 students of SMA Teuku Umar Semarang in the 2024/2025 academic year. The research instruments included critical thinking questions and student response questionnaires. Previous research showed that the PBL-based E-Worksheet

with ESD content was declared feasible based on validation and readability results, so it can be used for large-scale trials. The results of this E-Worksheet implementation study were quite effective in improving critical thinking skills with an N-gain score of 0.56 and were practical to use with a positive response of 78%. The implementation of this E-Worksheet also increased student awareness of sustainable household waste management. In addition, learning activities encouraged active student participation in solving problems relevant to everyday life. This indicates that the PBL-based E-Worksheet with ESD content supports the achievement of sustainable education goals at the secondary school level.

Keywords: Critical Thinking, E-Worksheet, Problem Based Learning, Education for Sustainable Development

Introduction

Education plays a crucial role in social life. An individual's level of education influences the transformation of society from a traditional one to a more advanced one driven by technology and science. Improving the quality of education is necessary to compete with other countries and prevent national backwardness. This presents a new challenge for educators, who must develop learning tools that focus on 21st-century skills. The Independent Curriculum itself follows 21st-century learning principles, encompassing four key skills students must possess: critical thinking, communication, collaboration, and creativity (Nimatuzahroh *et al.*, 2022) ^[9]. Critical thinking skills involve evaluation and decision-making, which are crucial for problem-solving. Students are able to make informed decisions when facing challenges (Firdaus & Wilujeng, 2018) ^[5].

Research by Widowati & Yonata (2023) ^[14] shows that low critical thinking skills are caused by teacher dominance in learning, which reduces active student participation. Students' critical thinking skills can be improved with one approach to problem-solving, namely the PBL (Problem-Based Learning) learning model (Cahyani *et al.*, 2021) ^[2]. PBL involves contextual problems that encourage students to analyze and evaluate information to find appropriate solutions. This learning is conducted in small groups with a tutor facilitating the discussion.

Observations with chemistry teachers at Teuku Umar High School in Semarang indicate that chemistry is often considered a difficult subject by students. Learning media still consist of government-issued textbooks, thus suboptimal student motivation for independent learning. The contextual approach to chemistry learning is also limited, resulting in a lack of understanding of the correlation between chemistry and everyday life. E-Worksheet is a learning tool that can increase student engagement in learning and facilitate independent learning (Khotimah *et al.*, 2020) ^[8]. This is also considered crucial for supporting the development of scientific literacy, critical thinking skills, and student awareness of environmental issues.

E-Worksheet uses green chemistry materials that focus on the development of environmentally friendly chemical processes in line with global efforts to achieve sustainable development goals (SDGs). ESD (Education for Sustainable Development) is one of the SDGs. ESD prioritizes the values of sustainability and environmental awareness. One environmental issue relevant to green chemistry materials is the problem of used cooking oil, which is largely produced by household activities and the food industry. Used cooking oil is vegetable oil that has been used for frying and is usually discarded after the oil turns dark brown. The ideal cooking oil is used once, but it is still suitable for use a maximum of three times (Rahayu *et al.*, 2020) [10]. Used cooking oil if used more than three times can cause various diseases (Ifa, 2017) [7]. If not managed properly, used cooking oil can have negative environmental impacts, such as water and soil pollution. Reusing used cooking oil to make laundry soap is one way to recycle waste oil. This method can promote sustainability and educate students about the importance of minimizing the environmental impact of everyday activities.

The development of E-Worksheet media combines the PBL and ESD learning models to enhance student engagement and develop critical thinking skills. Critical thinking skills are crucial for solving complex problems, analyzing information, and making informed decisions (Facione & Gittens, 2015) [3]. Through activities based on everyday

problems, students can be trained to identify problems, formulate solutions, and critically evaluate their learning outcomes.

Previous research has developed a PBL-based E-Worksheet with ESD content on the use of used cooking oil as a laundry soap ingredient to enhance students' critical thinking skills. This study aims to implement and evaluate the PBL-based E-Worksheet with ESD content on the use of used cooking oil as a laundry soap ingredient and disseminate the results to determine the response to its use in improving students' critical thinking skills.

Materials and Methods

This research is a quasi-experimental study, a follow-up to the development research (the develop and disseminate stages of the 4D model). The research design used was a one-group pretest-posttest design.

In the Develop stage, the designed E-Worksheet was assessed for feasibility through several procedures. Product validation included validation of materials and media by expert validators for appropriate content and presentation. Test and non-test instruments were validated by the validators to ensure the validity of the research data. A pilot test of students' critical thinking questions was conducted to analyze their validity and reliability. Critical thinking skills according to Ennis (1995) in Fatmawati *et al.* (2014) [4] are shown in Table 1.

Table 1: Indicators of Critical Thinking According to Ennis

Critical Thinking Skills	Skill Indicators
Providing Simple Explanations	1. Focusing on questions 2. Analyzing arguments 3. Asking and answering questions
Building Basic Skills	4. Analyzing the credibility of sources used 5. Making observations and considering them
Drawing Conclusions	6. Making deductions and considering the results 7. Making inductions and considering them 8. Formulating and making decisions
Providing Further Explanation	9. Defining and considering terms 10. Identifying and analyzing assumptions
Strategy and Tactics	11. Deciding on actions 12. Collaborating with others

The research procedure was implemented in several stages. First, students were given a pretest to determine their initial critical thinking skills. Next, an intervention was conducted in the form of learning using PBL-based E-Worksheet with ESD content. This was implemented over three meetings. Students were guided to solve problems, conduct soap-making experiments, and discuss their results according to PBL syntax. After the learning activities were completed, students were given a posttest using the same or equivalent instrument to measure improvements in critical thinking skills. In addition, supporting data was obtained through student response questionnaires to E-Worksheet and observations of learning implementation.

The subjects of this study were students of class X-3 of SMA Teuku Umar Semarang in the 2024/2025 academic year. At this stage, student responses to the E-Worksheet were collected using a response questionnaire. The data from the response questionnaire were analyzed descriptively quantitatively and with percentages. The pretest and posttest data were analyzed using N-gain. This analysis aims to determine student responses and the effectiveness of the PBL-based E-Worksheet with ESD content in improving

students' critical thinking skills. The dissemination stage of the revised product was disseminated in a wider scope in different classes.

Results and Discussion

Feasibility and effectiveness of E-Worksheet

The developed E-Worksheet product based on PBL with ESD content has undergone a series of validations covering aspects of material, media, test instruments, and non-test instruments. Material validation obtained a score of 71.9% with a feasible category, indicating excellence in aspects of suitability of learning objectives, use of easy-to-understand language, PBL syntax loading, contextual examples, and video media support, although still requires minor improvements. Media validation obtained a score of 78.3% and was declared feasible for trials, while the ESD-based critical thinking test instrument was also feasible with a score of 78.8% after revisions to the question indicators. The non-test instrument in the form of a readability questionnaire and student responses was declared valid with several suggestions for improvements related to content and accuracy of statements. A small-scale trial in grade XII

showed an average score of 75% with a high category, although the time aspect was a constraint because the allocation of only 3 JP was considered insufficient. The results of this study are consistent with previous findings that the integration of ESD in problem-based learning can improve students' critical thinking and readability skills so that the E-Worksheet product was declared feasible for use as a learning medium with minor revisions for improvement. The effectiveness of the PBL-based E-Worksheet with ESD content on Green Chemistry material was demonstrated through the posttest results obtained by students after participating in learning activities using the E-Worksheet. The instruments used were pretest and posttest questions of the same format, consisting of 15 questions designed based on critical thinking ability indicators. This aimed to determine improvements in learning outcomes and measure student competency achievement. The test was conducted online via the Google Forms platform with a 30-minute time allocation, facilitating data collection and ensuring efficient learning evaluation.

Analysis of the research results showed an improvement in students' critical thinking skills across the five indicators measured, as demonstrated by the comparison of posttest and pretest scores in Figure 1.

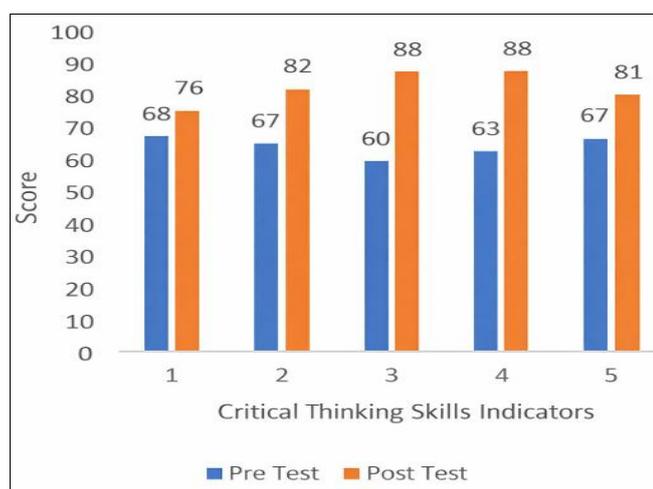


Fig 1: Comparison of pretest and posttest results

For the indicator providing simple explanations containing case studies of the application of green chemistry principles, the average pretest score obtained by students was 67.78, while the average posttest score increased to 75.56. Thus, there was an increase of 7.78%. This achievement is in line with the characteristics of problem-based learning that encourages students to analyze problems, connect green chemistry concepts, and develop skills in providing explanations. However, students' ability to provide simple explanations related to case studies of the application of green chemistry principles still does not reach the effective category. The cause is limited student understanding of the principles of green chemistry and relatively limited integration into the school curriculum. This condition has an impact on students' less than optimal understanding of green chemistry principles and their application in the context of case studies (Widyawati *et al.*, 2024) [15].

In the basic skills indicator, which includes the ability to find solutions, the analysis results showed a significant increase. The average pretest score obtained by students was 66.67, while the average posttest score increased to 82.22.

Thus, there was an increase of 15.55%, indicating that problem-based learning through E-Worksheet was able to encourage students to develop skills in finding solutions. Students were able to analyze the steps of the soap-making experiment from used cooking oil and choose actions that were in accordance with the principles of green chemistry, especially the principle of waste prevention. This is in line with the characteristics of PBL which requires students to think critically, identify problems, and find solutions based on relevant concepts. However, there are still obstacles faced, namely limited access for some students to electronic devices and a stable internet network. This condition can hinder the optimal use of E-Worksheet and potentially limit the development of their ability to find solutions to the maximum (Firtsanianta & Khofifah, 2019) [6].

The indicator for drawing conclusions includes predictions based on the data or information provided. The average score for this indicator was 60. The posttest score was 87.78, representing a 27.78% increase from pretest to posttest. Issue presentation still needs improvement to be more effective in drawing conclusions and honing students' critical thinking skills (Yani Putri, 2024) [17]. The indicator for providing further explanations includes the relationship between a case and relevant theories or concepts. The average score for this indicator was 63.3. The posttest score was 87.78, representing a 24.45% increase from pretest to posttest. Students can construct more in-depth explanations using the data presented. They can also choose the most appropriate explanation based on scientific considerations and environmental ethics. Students focus more on memorizing material without understanding the concepts in depth. A thorough understanding of green chemistry concepts is crucial because they will continue to be implemented in subsequent chemistry concepts and in everyday life (Sirmayeni, 2023) [12].

The "Managing Strategies and Tactics" indicator evaluates the effectiveness of strategies in solving a problem. The average score for this indicator was 66.67. The posttest score was 81.11, representing a 14.44% increase from pretest to posttest. This means students are able to evaluate various bioethanol fuel production strategies and select a combination of strategies that align with green chemistry principles to support sustainability and reduce environmental impact. However, a lack of interest in reading and literacy can impact students' critical thinking skills. Without good reading habits, students struggle to understand material deeply and develop effective strategies (Rizky Anisa *et al.*, 2021) [11].

The N-gain value obtained was 0.56, which is classified as moderate. This indicates that the effectiveness of this E-Worksheet is at a moderate level. This indicates that the implementation of the PBL-based E-Worksheet with ESD content can support the improvement of students' critical thinking skills in green chemistry learning.

Student Responses to PBL-Based E-Worksheet with ESD Content

A student response questionnaire regarding the E-Worksheet was administered after the learning process was completed to determine the practicality of the designed E-Worksheet. The questionnaire recapitulation obtained a score of 62.2, indicating that the E-Worksheet falls into the practical category. A summary of the percentage of student responses by aspect can be seen in Figure 2.

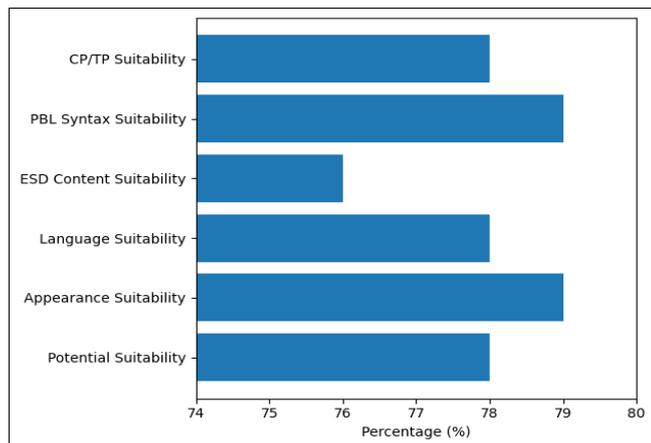


Fig 2: Percentage of Student Responses to E-Worksheet

Student responses to the assessment of the suitability of the CP (Learning outcomes) and TP (learning objectives) aspects received an average score of 94 with a percentage of 78%, indicating that it falls within the practical criteria. The E-Worksheet aligns with CP and ATP, meaning it is practical, facilitating students' understanding of green chemistry concepts and examples. Research by Ulandari & Mitarlis (2021) [13] shows that developing E-Worksheet aligned with core competencies and learning objectives can improve students' understanding of green chemistry concepts and enhance scientific literacy.

The assessment of the suitability of the PBL syntax aspect received an average score of 95 with a percentage of 79%, indicating that the E-Worksheet is effective in helping students analyze green chemistry principles used in the activity of using used cooking oil as an ingredient in laundry soap. The application of the PBL model to the E-Worksheet on green chemistry can improve students' critical thinking skills and learning motivation (Astutik, 2023) [1]. Student responses to this E-Worksheet indicate that the E-Worksheet is effective in helping them understand green chemistry concepts and their application in making soap from used cooking oil.

The critical thinking skills assessment aspect received an average score of 90.8 (76%), indicating that the E-Worksheet was practical in helping students analyze green chemistry principles used in designing laundry soap and conducting group discussions. This electronic LKPD is effective in developing 21st-century skills, including critical thinking (Wulandari & Cintamulya, 2022) [16].

The language assessment aspect received an average score of 93 (78%), indicating that the E-Worksheet was practical for students to understand the meaning of each sentence, image, and table. The display assessment aspect received an average score of 95.3 (79%), indicating that the E-Worksheet made it easy for students to access from mobile phones or laptops. The attractive display motivated students to learn. The potential assessment aspect received an average score of 93.6 (78%), indicating that the E-Worksheet had a positive impact and helped students complete the posttest questions.

Conclusion

The effectiveness of the E-Worksheet implementation is evident from the pretest and posttest analysis results, which indicate an increase in students' critical thinking skills across the five indicators measured. The highest increase occurred

in the conclusion-making indicator, while the basic solution-finding skills indicator also experienced significant growth. This indicates that the ESD-based PBL E-Worksheet is able to encourage students to more actively analyze, evaluate, and relate green chemistry concepts to contextual problems. Students' in-depth understanding of green chemistry principles and technical constraints such as device and internet access are factors that still need to be considered in further implementation.

Student responses to the use of the E-Worksheet fell into the practical category across various assessment indicators, including suitability of learning outcomes, PBL syntax, critical thinking skills, language, display, and potential for use. This positive response indicates that the E-Worksheet is able to improve students' understanding of green chemistry concepts and support critical thinking skills. Overall, it can be concluded that the ESD-based PBL-based E-Worksheet is feasible, quite effective, and practical for use in green chemistry learning, with significant potential for further development.

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